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ROOT AND CROWN INJURY OF APPLE TREES

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Root and crown injury of the apple tree, for many years a serious problem in the commercial orchards of New York, has become increasingly important with the progressive development of intensive culture and the attendant desire for solid blocks of trees of a uniform size and variety. General losses aggregate one-third, or even more, of the total number of trees in orchards. These have led during the past six seasons to observations and experiments looking toward the discovery of: (1) the cause of this type of injury; (2) methods for avoiding further injury; and (3) means of promoting the recovery of injured trees.

TABLE 1. ROOT AND CROWN INJURY IN SEVEN BLOCKS OF APPLE TREES IN WESTERN NEW YORK

Block no.	Varieties	Approximate age of trees (years)	Number of trees	Condition of trees in July, 1922		Increase in injury to May, 1925		Cultural conditions
				Number injured	Number replanted or dead	Number of new injuries	Number of new deaths	
1	Twenty Ounce	15–20	480	60	30	15	10	Poor up to 1922. Good thereafter
2	Wealthy Duchess	15–20	400	47	13	23	10	Poor
3	Baldwin..	15–20	104	2	1	1	1	Good
4	Mixed....	50–60	82	9	22	3	6	Good
5	Mixed....	8–10	61	2	1	0	0	Good
6	Mixed....	40–50	44	7	14	0	1	Good
7	Mixed....	50–60	33	5	7	2	2	Good

Orchard conditions in general which are unfavorable for most satisfactory growth of the trees, render them more liable to root and crown injury. This is indicated in table 1, which summarizes records of seven blocks of trees covering the period from July, 1922, to May, 1925. The trees included here are those in which the injury was sufficiently

[1] The writer wishes to acknowledge indebtedness to the Chase Bros. Nursery Co., of Rochester, New York, which supplied the apple seedlings used in this work; to J. T. Bregger, of the Stark Bros. Nurseries & Orchards Co., of Louisiana, Missouri, for the selection of the cion-rooted trees; and to the various growers in whose orchards the experiments were made.

advanced to cause them to show symptoms of thinning and paling of the foliage. Many additional trees showed some killing of tissue at the crown. Blocks 4, 5, 6, and 7 represent only the more severely injured parts of orchards, while blocks 1, 2, and 3 represent entire plantings. Blocks 3 and 2 are adjacent to each other and the trees are approximately of the same age, differing apparently little except in culture and variety. In block 2 seven trees, and in block 1 three trees, had recovered during this period.

DESCRIPTION OF THE INJURY

Evidence of root and crown injury is usually first noted on the parts of the tree above ground. The foliage becomes pale and sparse. Terminal growth is shortened or almost entirely wanting. The fruit is undersized and of poor quality. In some instances the bark is distinctly reddened and may show longitudinal cracking on the larger branches. Only a part of the tree may show these symptoms while the remainder appears to be unaffected. A heavy growth of shoots may arise near the base of affected trees. The conditions under which the trees are grown may influence considerably the character of the symptoms. For example, trees under poor cultural conditions exhibit a more marked yellowing of the foliage and reddening of the bark with a given amount of injury.

Most, if not all, of the symptoms described thus far are common to other types of injury at or near the base of the tree, such as girdling by rodents. The direct and more important evidence of injury is obviously found on the crown and the roots themselves. Most commonly the bark is killed on the crown and the upper lateral roots near the base of the trunk. In more severe cases or in successive seasons, the death of entire roots occurs and injury to the bark may extend up the trunk to a distance of two feet or more, particularly on certain varieties such as Ben Davis, Twenty Ounce, and King. The bark tends to separate in shreds from the wood. The affected wood usually remains brown and firm, often until the tree is entirely dead. In some cases the whitish mycelium of a fungus of the mushroom type is found on the surface and in the interior of roots, causing a punky rot. Death of trees comes about very gradually as a rule, altho the later and more conspicuous stages may succeed one another very rapidly at times of severe or prolonged drouth when the trees bear a maximum load of foliage and fruit.

In contrast to this injury, the black root-rot of the southern orchard sections involves the entire root system and is usually limited thereto. It reduces the roots to a punky condition so rapidly that a tree ten or twelve years old may be uprooted by hand before the top is entirely dead. Numerous dark lines mark the zones of advance of the fungus into the wood, and a dark stromatic incrustation of the causal fungus (Xylaria) is often formed on the surface of the roots.

ETIOLOGY

During the earlier part of this work, attention was directed toward the fungi which were found associated with the injury. An attempt was made, thru isolations from injured tissue and by collecting the fungous fruiting bodies that arose from such trees, to establish a constant

relation between some one of the organisms obtained and the injury under observation. Two fungi were found which seemed worthy of consideration. These were *Xylaria Polymorpha* (Pers.) Grev. and *Hyholoma sublateritium* Fries.

Xylaria Polymorpha was first studied in association with root rot of apple in Virginia (Fromme and Thomas, 1917). Preliminary experiments indicated that this fungus was at most only mildly pathogenic. Dr. F. D. Fromme stated, in conversation in 1920, that the fungus had shown little advance on trees in the field since its discovery in 1916. This species is rarely found on apples in Virginia, as compared with *X. digitata* (Linn.) Grev. *X. Polymorpha* has been found by various workers in at least twenty-two orchards in five counties in western New York, while to the writer's knowledge *X. digitata* has not been seen on the apple anywhere in the State. However, culture work and a search for the stromata of *X. Polymorpha* have not shown this fungus to be abundant in the orchards in which it has been found.

Several inoculation experiments were performed to test the pathogenicity of *X. Polymorpha*. Apple roots were inoculated in the laboratory by the method described by Fromme and Thomas (1917). The fungus grew readily on apple branches, but on four roots that remained alive and active (as was evidenced by their putting out shoots) it had not advanced beyond 3 millimeters into the wood after seventy-four days.

Five seedling apple trees and four seedling pears growing in the greenhouse were inoculated by cutting thru the bark below the ground level and packing several kernels of corn, bearing the fungus, close around the stem near the wounds. Five apple trees were similarly wounded for controls. Approximately three months later the control trees, three of the inoculated apple trees, and two of the pear trees, had healed their wounds completely. In the four remaining trees the fungus had penetrated the bark along an area from 5 to 20 millimeters in length and in the apple trees had penetrated the wood slightly.

On August 25, 1922, seven inoculations were made on roots and crowns of four seedling apple trees, from two to six years old, growing in a garden at Forest Home, near Ithaca. The inoculations were made by inserting a bit of mycelium from a pure culture into the bark thru a knife wound. These trees were examined on October 12, 1923. Of the six wounds that were found, two were completely healed and the remaining four showed slight killing in the bark extending a few millimeters from the point of inoculation. In no case was the wood penetrated to a depth of more than 2 millimeters.

A more extensive experiment was begun in the spring of 1923. On May 2, twenty apple trees each of the varieties Tompkins King, McIntosh, Fameuse, and Baldwin, and twenty-five trees of Northern Spy, were planted at 20-foot intervals. Ten of the Northern Spy trees and five each of the remaining varieties were inoculated immediately before planting, in the following manner: A cut was made in the bark of the crown tangential to the surface of the main stem, and the bark was raised just enough to permit the insertion of a wheat kernel heavily charged with mycelium of the fungus. The bark was pressed down, crushing the inoculum between the bark and the wood, and the trees were planted at

once. The trees were inspected, but not uprooted, on October 14, 1925. Of the thirty trees inoculated in this manner, six had died. Four of these were of a single variety, Fameuse. Of fifty control trees, six were dead.

From these experiments it is apparent that, on young trees, *X. Polymorpha* can penetrate living bark and wood at the most very slowly, and in many cases does little more than aggravate the wound into which it is introduced. It should be noted here that these inoculations were all on young wood, whereas in the field the fungus is most commonly associated with the dying of trees from twelve to fifty years old. Yet the evidence at hand indicates that the behavior of the fungus on older trees which are well kept, is not unlike that on younger trees. Inoculations thru wounds on the roots of a single neglected tree from thirty to forty years old caused slight injury in three months, but at the end of sixteen months the injury had been thrown off. It has been noted further that the presence of this fungus on older trees did not seem to interfere with the success of the approach grafting, which is described later in this paper.

Hypholoma sublateritium Fries, a fungus of the mushroom type, has been identified from only two sources but is probably more generally distributed than is indicated by these records. Murrill (1899) found this fungus in 1899 on a single crown-rotted tree of the Tompkins King variety, and suggested the possibility of its being the cause of the injury. In the spring of 1925, a fifty-years-old Baldwin orchard in Orleans County showed a loss of trees in a rather definite spot, where four trees had recently died and five others were severely injured. One of these injured trees died before the close of the season. On the roots of four of these trees a heavy growth of dense white mycelium was present on both living and dead bark, and from one of these the fruiting bodies of *Hypholoma sublateritium* arose in profusion. The fungus was identified by Dr. H. M. Fitzpatrick. Cultures from this source, and cultures of the same fungus received on an apple-tree stump from Westchester County, were used to make inoculations similar to those described above for *Xylaria Polymorpha.* With the culture from Westchester County (*Hypholoma* A), four uninjured apple seedlings were inoculated in the greenhouse on March 3, 1924. When uprooted on August 11, these plants were as healthy as the control plants. A similar experiment was made on February 26, 1925, in which twenty apple and twenty pear seedlings were used with controls. No apparent injury had resulted on September 18, 1925. On July 1, 1925, *Hypholoma* A and *Hypholoma* B (the Orleans County culture) were each used to inoculate sixteen trees, including five varieties, planted in 1923 on the university farm. The inoculum was inserted beneath the bark at the crown. On October 14, 1925, two trees in each lot showed enlargement of the wound, which in the case of culture B was somewhat greater than with culture A. The remaining wounds were closed or nearly so, even on trees infested by borers. On July 16 and July 22, 1925, cultures A and B were introduced thru wounds into the roots of four trees, from forty to fifty years old, in a sod orchard. These were examined on October 8, 1925. Of twenty-two wounds made for culture B, five had healed; the remainder showed dis-

coloration of the wood up to a breadth of 2 inches, and a spread of the white mycelium over and into the bark to a distance, in some cases, of 3 inches or more from the wound. With culture A, of eighteen wounds only two showed an abundance of the mycelium and six showed little, if any, injury to the wood. In five, however, the wood was discolored for 1 inch or more from the point of inoculation. It seems certain, therefore, that this fungus is capable of killing the bark and the wood of apple trees which are already injured. That it does any extensive damage at large in the orchards of the State may well be held in question.

Except for these two organisms, none has been found which seems to raise serious question of its being the cause of root and crown injury of the apple. The field observations have been supplemented by isolations from orchards both in western New York and in the Hudson River Valley. No important relation is apparent between this injury and the occurrence of fire blight in orchards. *Physalospora Cydoniae* Arnaud and *Cytospora* sp. obtained from apple cankers above ground were unable to persist in wounded roots of old trees in a single experiment. It has frequently been observed that orchards which show injury at the crown, in severe cases show also symptoms typical of freezing injury above ground (Mix, 1916). This was true particularly of the injury following the severe winter of 1917–18. Since, therefore, the root and crown injury itself in earlier stages agrees, as far as can be determined, with that caused by low temperature, the writer is of the opinion that freezing is the initial cause of the greater part of this type of injury to apple trees in New York.[2] The tendency for the injury to be localized in the crown and the upper roots may be explained by the fact, now generally recognized (Chandler, 1913), that the tissue in that region matures more slowly than does the tissue above ground, and is thus more susceptible to freezing injury. It has been observed further that trees which show this crown injury respond readily to the handling recommended for trees injured by freezing: namely, application of fertilizer and early cultivation followed by practices that check growth in the latter part of the season, combined with the development of a cover crop or the use of a protecting mulch for the winter months.

PREVENTION AND RECOVERY

In addition to the standard orchard practices just mentioned, certain other means may be employed in preventing root and crown injury. Drainage of low-lying land with a high water table will permit the development of a deeper and more vigorous root system, thus avoiding exposure to freezing and to other injury as well. Mounding of the soil around the base of the trunk in late autumn may be beneficial, but the mounds should always be removed during the growing season.

Approach grafting as an aid to the recovery of injured trees

Approach grafting has been recognized for a number of years as a means of reviving trees that have been injured on trunk, crown, and roots (Oskamp, 1918, Alderman and McGrath, 1922, and Yerkes, 1923).

[2] Grossenbacher (1912), in numerous field observations in New York extending over a number of years, noted that crown rot was initiated during the winter months but attributed the injury to other factors than direct freezing.

One grower in Orleans County used this method with some success as early as 1915. It consists essentially in planting apple seedlings or ordinary nursery stock close to the crown of the injured tree, and grafting the tops into the trunk or the crown near the lower margin of the sound bark (as shown in the illustration on the cover of this bulletin). In the spring of 1923 a preliminary experiment was made with twenty grafts on trees in a single orchard. The results were so gratifying that in May, 1924, 208 seedlings were used in six orchards in four counties of western New York. Forty trees were treated in this experiment. From September 15 to September 17, 1924, these were examined and it was found that 189, or 90.9 per cent, of the grafts had been successful and most of them had made a satisfactory growth. Only six of the seedlings had died completely. In early May, 1925, 196 of these grafts were again examined, and, surprisingly enough, 176, or 89.8 per cent, of these were found to have survived the winter in good condition.

The question may well be raised as to the permanence of these seedling grafts, since the stock is presumably of the same heterogeneous sort as that on which the trees were originally planted. With this in mind an effort was made to obtain grafted or budded stock on its own roots, of varieties believed to be more hardy than the crab (Craig, 1900, Chandler, 1913, and Potter, 1924). Thru the cooperation of J. T. Bregger, of the Stark Bros. Nurseries and Orchards Co., nursery trees of McIntosh and Delicious which had produced roots from the cion were obtained for the season of 1925. Of these, 120 were used without cutting away the seedling stock, in May, 1925, in five orchards in four counties. While there did not seem to be a sufficient number of cion roots to permit of removing the crab stock, it was believed that, with relatively deep planting, these would develop in the position in which roots would be most exposed to injury. On September 25, 1925, 98, or 81.6 per cent, of these grafts had made a good union with the trees, and 9 of them had died. Growth of these grafts did not seem to be quite as vigorous in general as did that of the seedlings, altho many of the grafts had made a vigorous growth.

After two seasons of growth under favorable conditions the seedlings have reached a diameter of from $\frac{3}{8}$ inch to $1\frac{1}{8}$ inches, averaging perhaps about $\frac{5}{8}$ inch. The trees in general show the expected gradual return of vigor. The results thus far, however, emphasize the necessity for beginning the treatment early, that is to say, before the development of marked yellowing and thinning of foliage. The crowns and the roots of trees should be examined at the first indication of these symptoms, and prompt treatment is even more important than in bridge grafting. Certain other precautions taken in bridge grafting may be applied equally well here, as, for example, the use of vigorous seedlings or other trees and the removal of shoots from the grafts. Indeed, in many cases in which the injury is local at the crown, a true bridge graft could be profitably employed. Not infrequently shoots may arise from below the injured part of the crown in a position to be profitably grafted into the trunk above.

Several more years will be required to determine the exact benefit to be derived from this treatment and to permit a choice between seedling stock

and cion-rooted trees for use in restoring injured trees. Since seedlings can be purchased for $4 per hundred or less, and since an average of about five grafts to each injured tree may be required, a distinct superiority must be demonstrated for the more expensive types of stock to justify their use. In any event, the results thus far indicate that this type of treatment will prolong the life of bearing trees for at least a considerable number of years, with a profit greatly in excess of the relatively low cost of the operation.

SUMMARY

Root and crown injury is general in the orchards of New York, and causes a slow but eventually serious loss of trees in many instances.

No pathogenic microorganisms have been found to be constant in association with this type of injury.

Hypholoma sublateritium is able to cause decay in the bark and the wood of injured roots on old trees. A limited distribution of this fungus in orchards is indicated.

As a result of these and other observations and experiments, the writer is led to the conclusion that the greater part of the crown and root injury of apple trees in this State is initiated by low temperatures.

Standard orchard practices are suggested as means of avoiding the injury.

Approach grafting, with apple seedlings and with cion-rooted McIntosh and Delicious stock, has given considerable promise as a method of promoting the recovery of injured trees.

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